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THE SOILS AND VEGETATION AT TIDAL RIVER, WILSON'S PROMONTORY

By R. F. Parsons

Botany Department, University of Melbourne

Abstract

The soils and vegetation of 1·25 square miles of country around Tidal R., Wilson's Promontory, are described and mapped. The relationship between soil type and vegetation type is discussed. Distinctive groups of associations are recognized on each of the major soil subdivisions; viz.—calcareous sands, siliceous sands, granitic soils, and peaty soils. Within each of these subdivisions water relations appear to be the main determinants of vegetation type. However, exposure to salt spray and tidal inundation are more important in some areas. A species list for each of the plant associations is appended.

Introduction

A number of characteristic plant associations are widespread along the coastlines of SE. Australia, e.g. in SW. Victoria (Gibbons & Downes 1964), King I. (Stephens & Hosking 1932), Flinders I. (Dimmock 1957), NE. Tasmania (Hubble 1946), and New South Wales (Pidgeon 1942). However, the only comprehensive accounts of the plant ecology of these associations are those of Turner, Carr, & Bird (1962), who made a successional study at Corner Inlet, Victoria, and Pidgeon (1942) who has discussed the vegetation of coastal areas in New South Wales.

This paper examines in detail these plant associations in the area around Tidal R., Wilson's Promontory.

The Study Area

Wilson's Promontory is situated approximately 150 miles SE. of Melbourne. It is the most southerly part of mainland Australia (Fig. 1).

An area of approximately 1¼ square miles was selected at Tidal R. The location of the area may be seen in Fig. 1 and 2.

As Wilson's Promontory was declared a National Park in 1905, much of the study area is relatively undisturbed by man. However, 80 acres occupied by a tourist camp, and smaller scattered areas, disturbed during army occupation in 1939-1945, are considerably altered.

The principal aims of this project were:

(1) to record the plant species present and their frequency over the area, and to map the plant associations present, and

(2) to describe and map the soils of the area, in an attempt to elucidate some of the reasons for the observed distributions of the plant associations.

Methods

An aerial photograph of the area was marked with a 10-chain grid, and at each grid intersection the species present and their frequency were determined using random quadrats. A nest of quadrats was used, and the species recorded at ¼, ½, 1, 2, 4 square metres. The nest was repeated at random five times. The soils were

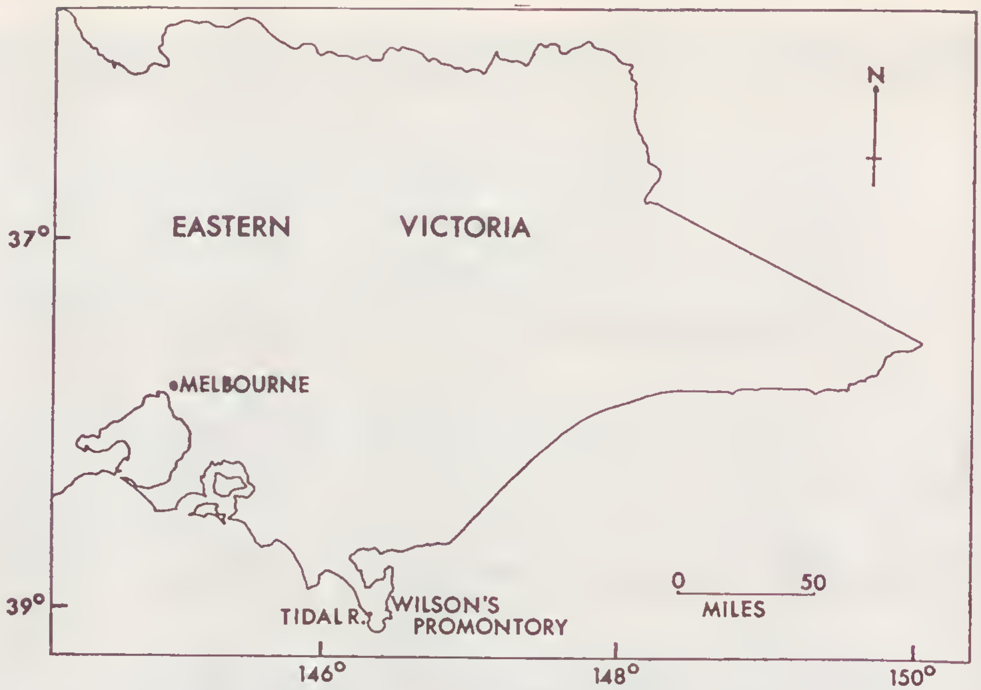

FIG. 1—Locality plan, showing Tidal R., Wilson's Promontory.

surveyed by auger holes at each grid intersection to a depth of 10 ft where practicable. Supplementary examinations were made where necessary.

The field work was carried out from February to September 1962. Consequently some annual and ephemeral species have escaped attention and the identification of *Gahnia, Leptocarpus*, and some grasses has been possible only to generic level. Plant names follow Willis (1962) for Pteridophyta and Monocotyledoneae, and those used by the staff of the National Herbarium of Victoria for Dicotyledoneae. Taxonomically difficult specimens were checked by the National Herbarium of Victoria, and lodged in the herbarium of the Botany Department, University of Melbourne.

Geology and Physiography

Wilson's Promontory is composed of rugged granitic hills, with some Quaternary deposits around the coastline. The general topography of the Promontory can be seen in Fig. 2. Areas above the 200 ft contour line can be assumed to be granitic, and areas below this altitude are composed of granite, granitic colluvium or Quaternary deposits (principally sands and peats). The highest of the granitic hills is Mt Latrobe (2,475 ft). Some contour lines in the study area are shown in Fig. 3.

(a) The Granite

The granite is a grey, coarse-grained, massively-jointed porphyritic granite containing felspar crystals up to 4 in. long and 2 in. wide. Quartz, orthoclase, subordinate plagioclase, and biotite are the main minerals. Black tourmaline is widely distributed. The granite is considered to be of Devonian age, but there is no direct evidence to establish the age more precisely (Reed 1959).

FIG. 2—General topography of Wilson's Promontory, showing Tidal R. (from Frankenberg 1965).

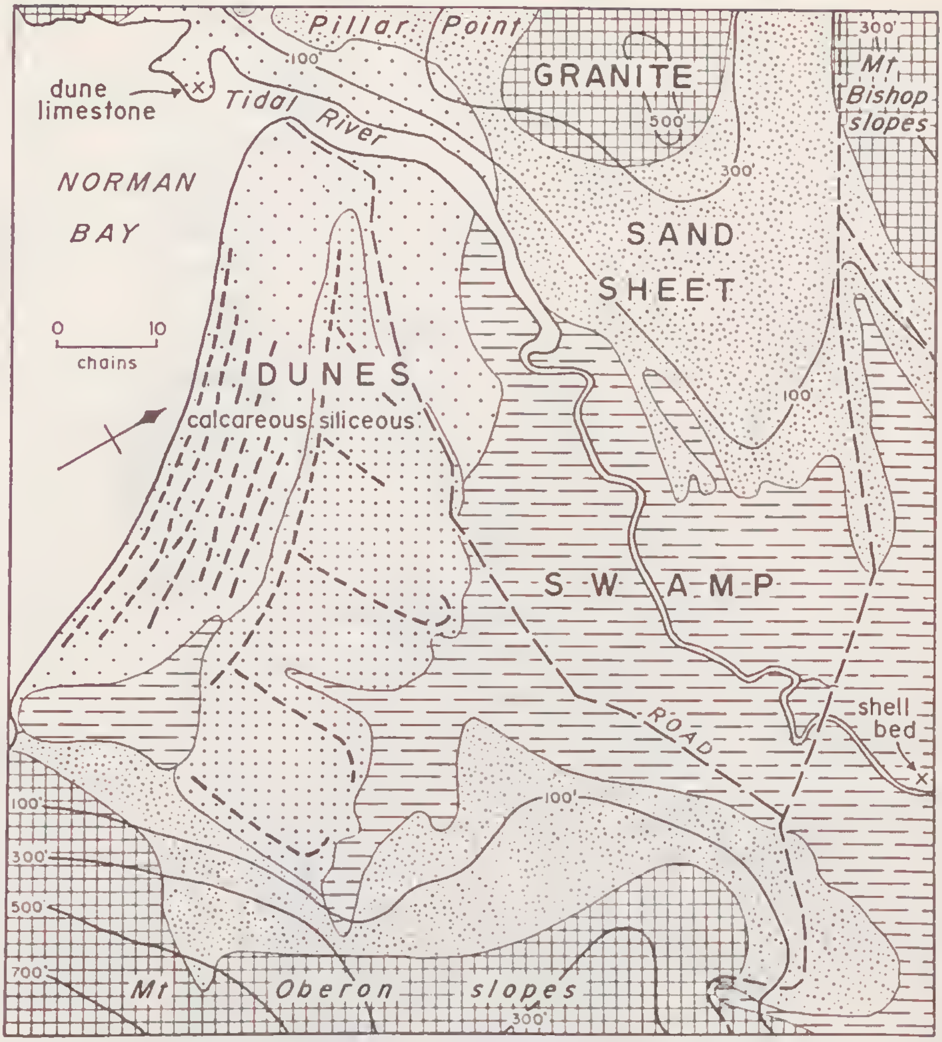

FIG. 3—Map showing landforms, major dune ridges, localities referred to in the text, and some approximate contour lines.

(b) QUATERNARY DEPOSITS

These occupy relatively small areas of the Promontory. However, about three-quarters of the study area is occupied by beach-derived sands, which occur alone, or mixed with either peat or weathered granitic detritus washed down the slopes of the adjacent hills.

The beach-derived sands of the area have accumulated in the bay formed by Pillar Point and Norman Point (Pl. 36, fig. 1). They extend from the present shoreline at least to the NE. boundary of the study area, where they are overlain by peat deposits.

(i) THE DUNES

A series of calcareous parallel dunes is present behind the strandline. Storm waves have removed the embryonic dunes, producing a sand cliff rising from the beach.

Mr W. Tuddenham, Department of Geography, University of Sydney (pers. comm.) considers that the calcareous sand area is composed both of wave-laid beach ridges (berms) and wind-laid dunes. No attempt has been made to distinguish these two categories, and in the text both are referred to as 'calcareous parallel dunes'.

Aerial photographs and field work show at least seven calcareous parallel dunes in the area. Their location is mapped in Fig. 3. These dunes, like the beach itself, are calcareous, comprising a mixture of siliceous particles mixed with broken shells from marine beds.

The dunes are of low relief, rarely being more than 10 ft from ridge to swale, and are closely spaced (about 70 yds from ridge to ridge). These dunes seem to be equivalent to the calcareous 'New Dunes' reported by Jennings (1959) on King I. Jennings considered these 'New Dunes' to be of Recent age.

Immediately behind the calcareous parallel dunes, there is one long siliceous parallel dune (Fig. 3). At the NW. end of Norman Bay this dune, in general, is much higher than the adjacent calcareous parallel dunes. Survey levels in this area show that the heights of the calcareous parallel dunes are from 22 to 26 ft above high-tide level, while the siliceous dune varies in height from 31 to 80 ft above high tide level (levels from the National Parks Authority, Melbourne).

Landward from the siliceous parallel dune there is an area of parabolic dunes (Fig. 3). These parabolic dunes are siliceous and show similar soil features to the 'Old Dunes' on King I., which Jennings (1959) considered to be of late Pleistocene age.

Featureless sheets of siliceous sand occur banked against the lower granitic slopes of Mt Oberon and Pillar Point (Fig. 3). That these sands have been affected by downwashed granitic detritus is indicated by the scattered occurrence of quartz gravel throughout the soil profiles examined.

The sequence of 'New' calcareous dunes on the coast and 'Old' siliceous dunes farther inland is known from other parts of the Australian coast (Bird 1964), and it is usually assumed that the siliceous dunes are derived from the calcareous dunes by removal of the shell material by leaching. The sand on Norman Bay beach is calcareous ($CaCO_3$ = 35-40%). However, the sand on the adjacent Leonard Bay beach is almost pure silica ($CaCO_3$ = 0·1-0·6%), and it is possible that the Norman Bay siliceous dunes were built up at a time when the Norman Bay beach sands were siliceous. Whatever the parent material, the Norman Bay parabolic dunes show evidence of marked leaching, and are clearly much older than the calcareous dunes.

Dr E. C. F. Bird, Australian National University, Canberra (pers. comm.) considers that the parabolic dunes in the study area have been derived by rearrangement of parallel dunes older than the calcareous ones, and that the sand sheets are relics of a still earlier phase of dune formation. It is also possible that they are sublittoral sand sheets deposited during a Pleistocene period of higher sea level. There appears to be no means at present of deciding whether the parabolic dunes are of the same age as the siliceous parallel dune and partly derived from it, or whether they are derived from older parallel dunes now no longer existing.

Various types of dune limestone are common along the Victorian coast and, on Wilson's Promontory, dune limestone is conspicuous at Darby R. and at Oberon Bay. However, in the study area, dune limestone was only located in one small area on top of a small granitic hill adjoining Pillar Point near the mouth of Tidal R. (Fig. 3). This hill consists of calcareous sands overlying granite. The dune limestone occurs as two to three bands of limestone interstratified with unconsolidated calcareous sands. No bedding planes are visible in the limestone itself, which consists of sand grains cemented together by secondary calcium carbonate. Similar deposits elsewhere in southern Australia are probably of Pleistocene age (Bird 1964).

(ii) Swamp Deposits

A low-lying swamp occurs along the banks of Tidal R. This consists of peaty soils overlying beach-derived sands, at altitudes less than 25 ft above high tide level. Where Tidal R. crosses the NE. boundary of the study area, a shell-bed was found buried underneath 4 ft 4 in. to 6 ft of peat and sand (Fig. 3). The shells occurring in this bed were kindly identified by Professor J. W. Valentine, University of California, Davis, California, U.S.A., and are listed in Table 1. The shell species present indicate an estuarine origin for the deposit, e.g. *Salinator fragilis* is an air breather living in backwaters of beaches (lagoons) more or less under the influence of fresh water.

Table 1

Species List of Shells from the Buried Shell-bed

Frequencies: A = abundant C = common R = rare

Species	Frequency
Cacozelania granaria	C
Austrocochlea constricta	C
Legrandina benardi?	R
Homalina deltoidalis	R
Conacmea alta	R
Zeacumantis diemenensis	C
Polinices cf. *sordidus*	R
Velacumantis australis	C
Soletellina biradiata	R
Niotha pyrrhus	R
Parcanassa pauperata	R
Acteocina fusiformis	R
Cylichnina pygmaea	C
Salinator fragilis	A
Mysella donaciformis	R
Melliteryx helmsi	R
Lepton trigonale	R
Katelysia peroni	A
Diala semistriata	A
Diala pagodula	R
Pseudoliotia micans	C
Batillariella estuarina	R

Mr E. D. Gill, Assistant Director, National Museum of Victoria, has kindly supplied a radio-carbon dating for the shell-bed. The age was found to be 6230 ± 430 years (Ac-12). According to Gill (1955, 1964) this date places the shell-bed in the Postglacial Thermal Maximum, a period of warmer climate with a sea-level approximately 10 ft higher than at present in Australia. The level of this deposit relative to mean high water spring tides has not been determined. However, Gill (pers. comm.) states that similar emerged shell-beds occur frequently along the coast of Victoria at about the same elevation. He regards them as products of a Recent 10 ft stillstand and the succeeding emergence.

The radio-carbon dating indicates that a depth of 4 to 6 ft of swamp deposits has been built up in the last 6,000 years.

The peaty deposits that occur along Tidal R., then, may be regarded as products of coastal emergence and consequent invasion by swamp plants. It is probable that deposition and erosion by both tidal movements and by fresh water draining through Tidal R. have also affected their formation.

It appears that the complex topographic and vegetation pattern in this small area must be considered against a background of sand deposition and redistribution, leaching and Recent coastal emergence; it will also depend on changes of climate and sea-level, at least during the Pleistocene (Bird 1964).

Climate

The nearest meterological station to the study area is approximately 12 miles to the south at the Lighthouse on the southern tip of the Promontory. Graphs of mean monthly climatic data (rainfall, temperature, and length of day) from this station have been published by Groves and Specht (1965). The following brief account of climate is taken partly from unpublished wok of Groves (1964).

Rainfall data at Tidal R. itself are available from 1951 (Table 2). Mean annual rainfall is 43 in. The monthly means show maxima in May and June, and minima in December and January. Rainfall variability has been expressed as the mean deviation from the mean as a percentage of the mean (Table 2). Calculations show that the growing season for agricultural crops, on the basis of $P/s.d.^{(0 \cdot 75)} > 4$ (Prescott & Thomas 1949) is almost 12 months. This index is a broad generalization useful for regional comparisons; within the study area there will be considerable variation in the growing season with topography, soil type, microclimate, and plant species.

As would be expected in a maritime location, temperatures are moderate (Table 2) and frosts are rare.

NW. to SW. winds predominate on the Victorian coast (Anon. 1944). Wind data are available for the Lighthouse station as observer estimates for 9 a.m. and 3 p.m. The monthly prevailing wind direction is W. for all months except July (NW.), August (NW. and W.), and December (W. and NE.). It follows that E. and SE. aspects will be considerably more sheltered from wind than W. and NW. ones and consequently will be characterized by lower evapotranspiration rates. Mean monthly wind speeds show no seasonal trends; they vary from 13 to 18 miles per hour at 9 a.m., and from 12 to 17 miles per hour at 3 p.m. These speeds are similar to those at other exposed coastal locations in southern Australia, where wind speed diminishes quickly with distance from the coast (Anon. 1944).

Biotic Influences

The most important grazing animals present in the area are the introduced species *Cervus porcinus* (hog deer), and *Oryctolagus cuniculus* (rabbit); and the indigenous *Protemnodon bicolor* (swamp wallaby), *Phascolomys mitchelli* (wombat), *Trichosurus vulpecula* (brush-tailed possum), and *Pseudocheirus peregrinum* (ring-tailed possum).

The effect of grazing on plant distribution has not been investigated. However, the presence of localized heavily-grazed areas indicates that it may well be important.

TABLE 2

Climatic Data for Wilson's Promontory, Victoria

(After Groves 1964)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly Total
A. RAINFALL (pt)													
Tidal R. (1951-1962)	161	219	230	377	539	523	480	483	342	403	346	214	4317
Mean deviation % of mean (Tidal R.) ..	63	52	77	54	51	50	41	43	30	40	43	41	19
B. TEMPERATURE (°F)													
Lighthouse (1911-1940)													
a. average daily max.	66·7	68·2	66·4	62·3	58·6	55·1	53·9	55·1	57·3	60·3	62·2	65·1	60·9
b. average daily min.	56·9	58·7	57·4	54·7	52·1	49·0	47·7	47·7	48·8	50·3	52·2	55·1	52·6
c. average daily mean	61·8	63·5	61·9	58·5	55·3	52·1	50·8	51·4	53·0	55·3	57·2	60·1	56·8

Fire

The fire history of the area is undocumented. The most recent large-scale fire in the study area was in 1951, giving rise to two distinct ages of vegetation in a number of communities. All the associations of the area except the salt-marsh and the *Cyperus lucidus-Phragmites communis* grassland show clear evidence of having been burnt at some time in the past. Fire can be expected to have a marked temporary effect on species composition, as indicated for heath (Specht, Rayson, & Jackman 1958) and dry sclerophyll forest (Wood 1937) in South Australia.

Soils

The soils are generally similar to the soils of coastal areas elsewhere in southern Australia (see, e.g., Dimmock 1957, Hubble 1946). They consist of beach sands in various stages of profile differentiation, and peaty soils in poorly drained areas. On hillsides, soils derived from granite also occur.

The soils have been classified according to the factual scheme of Northcote (1965) and their distribution mapped (Fig. 4).

(a) Soils Derived from Beach Sands

These soils vary from the undifferentiated most recent sands to older, markedly leached sands.

(i) Soils of the Calcareous Dunes

There are 4 to 7 parallel calcareous dunes behind the present strandline. Calcium carbonate content of the surface 6 in. declines from 35-40% on the beach and foredune to 7% on the most leeward calcareous dunes.

The soils are of the Uc1.11 principal profile form. They show no obvious profile development except for organic matter accumulation on the surface. This varies from very small amounts of organic matter on the recently stabilized sands, to a marked A horizon with organic staining to about 20 in. deep under mature *Leptospermum laevigatum* thicket.

A description and some analyses of a leeward dune profile beneath mature (24 ft high) *L. laevigatum* thicket are given in Table 3 (all analyses by the methods of Piper (1942), except that phosphorus is reported as total P dissolved by 4 hours boiling with concentrated hydrochloric acid, and determined by a colorimetric reduced-molybdate method).

pH increases down the profile as a result of leaching of calcium carbonate from the surface horizons. The high alkalinity of this soil type causes low availability of

Table 3

Description and Analyses of a Uc1.11 Soil

Sample Site: 5* Vegetation: *Leptospermum laevigatum* thicket

Depth (in.)	Horizon	Description+	pH	$CaCO_3$ (%)	P (%)
0–3	A	Dark brown slightly coherent organic sand	7·5	6	0·076
3–6	A	Dark brown slightly coherent organic sand	7·6	8	0·073
6–12	A	Dark brown slightly coherent organic sand	7·8	10	0·064
24–36	C	Pale brown loose shell sand	8·2	35	0·057

* For location see Fig. 5.

+ All soil colours as Munsell colours on moist sample.

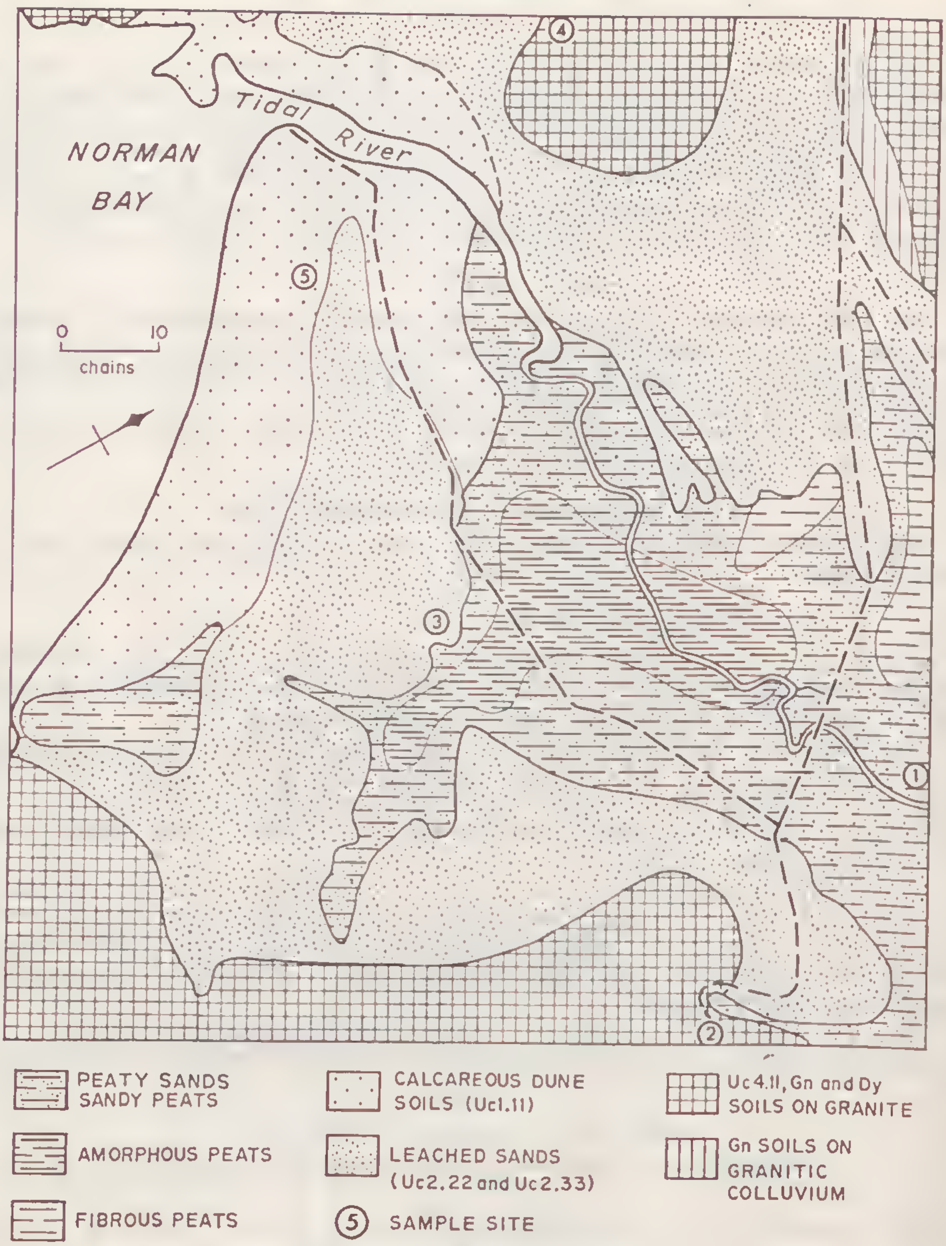

FIG. 4—Soil map of the study area.

copper, zinc, iron, and manganese (Truog 1951). Although the total phosphorus content is high (due to the phosphorus accumulated by some species of shells, Thomas 1938), similar soils have been shown to be deficient in the amount of phosphorus available to agricultural species (Dimmock 1957).

(ii) Soils of the Siliceous Dunes and Sand Sheets

These soils have developed on beach-derived sands landward from the calcareous dunes. They occur on siliceous parallel and parabolic dunes and on featureless sand sheets banked against the granitic slopes of the area. There are two types.

(1) Uc2.22 soils. These are leached sands darkened by organic material in the surface soil with a bleached A_2 horizon and with a coloured and mottled, but not compacted B sand horizon.

A description and some analyses of a profile taken from the top of a parabolic dune are given in Table 4. From the analyses it can be seen that these soils have

Table 4

Description and Analyses of a Uc2.22 Soil

Sample Site: 3 Vegetation: *Casuarina pusilla-Leptospermum myrsinoides* heath

Depth (in.)	Horizon	Description	pH	$CaCO_3$ (%)	P (%)
0–3	A_1	Black slightly coherent organic sand.. ..	5·7	nil	0·006
3–6	A_1	Dark grey slightly coherent fine sand ..	5·5	nil	0·003
6–12	A_2	Light grey loose fine sand	5·4	nil	0·002
24–36	B_1	Mottled light grey, yellow and yellowish brown loose fine sand	5·7	nil	n.d.*

* n.d. = not determined

been leached completely of calcium carbonate. Consequently they are acidic and very low in phosphorus. The colouring in the B horizon is due to iron and organic matter leached down from the A horizons. Similarly, the B horizon is usually richer in phosphorus than the A horizons of such soils (Graley 1956). This is probably also true for other plant nutrients.

The depth to the B horizon from the surface is very variable—it may occur anywhere between 42 in. and 120 in. The boundary between the A_2 and B_1 horizon is extremely irregular. The B horizons examined all continued for at least 56 in. They occurred either as loose or slightly coherent sand.

Field determinations of soil reaction by colorimetry indicated that the siliceous parallel dune has surface pH values ranging from 6·5 to 7·0, while the parabolic dunes more usually range from 5·5 to 6·0. This difference suggests that the parabolic dunes are older than the siliceous parallel dune.

The Uc2.22 soils occur on siliceous parallel and parabolic dunes and on the sand sheets, but always in elevated, well-drained positions. Where drainage is impeded a definite hardpan usually develops, giving rise to the Uc2.33 soils discussed below.

(2) Uc2.33 soils. These soils are similar to Uc2.22 soils except that a definite hardpan is present. This hardpan consists of sand grains cemented together by iron and organic matter (Pl. 37, fig. 1). It is called variously orstein, sandstone, and coffee rock. Uc2.33 soils occur both on the parabolic dunes and on the sand sheets. They have not been analyzed, but can be expected to have a comparable nutrient status to the Uc2.22 soils, being of similar age and parent material (cf. Graley 1956).

The depth to the B horizon from the surface is again variable, and in the soils examined was between 34 in. and 68 in. The boundary between the A_2 and B horizons is very irregular, the white sand of the A_2 horizon tongueing downwards into the hardpan and forming vertical columns up to 12 in. long. Dimmock (1957) believes these columns to be formed by channelling of drainage. The columnar hardpan itself is only a few inches thick—it forms a shell enclosing mottled coherent sand.

As mentioned before, a definite hardpan is developed in situations of impeded drainage. In the study area a hardpan usually occurs (a) where up to about 5 ft of sand occurred over the relatively impermeable decomposing granite of the lower hillslopes, and (b) in low-lying, poorly drained situations as a zone between well-drained sands without a hardpan and the peat soils of swampy depressions. A similar relationship between hardpan development and topography was noticed by Turner, Carr, & Bird (1962) and by Nicolls & Dimmock (1965).

A number of these soils show evidence of alteration by erosion and deposition of sand. At one site, a truncated profile was found with a weathered organic pan occurring right on the surface, and other profiles had two distinct organic pans separated by up to 30 in. of loose sand.

Gill (1965) has described Uc2.33 soils from Port Campbell and has established by radio-carbon dating that one such soil was composed of an A horizon of Upper Holocene age over a B horizon of Pleistocene to Lower Holocene age. This disconformity was attributed to stripping off of the original A horizon during the Postglacial Thermal Maximum. Similar instability in the Tidal R. area may account for the altered profiles described above.

(b) Soils Derived from Granite

These soils occur on the granitic hills and ridges of the area, which range in altitude from 50-700 ft. They are very variable, ranging from skeletal soils with a few inches of soil over bedrock, to soils up to 6 ft deep over decomposing granite. This variability occurred over such short distances that it was only possible to map all the soils on granite as one group. Such variability in soil depth has also been noted on granite and granodiorite by Holmes, Leeper, & Nicolls (1940).

The majority of soils on granite belong to Northcote's (1965) gradational (G) primary profile form and these will be considered first.

(i) Gn Soils

Because the soils were examined principally by auger holes and no data on the structure of the B horizons were obtained, it was not possible to completely classify them using Northcote's (1965) system. All that can be said is that these soils are Gn soils, i.e. gradational non-calcareous soils.

In general, the Gn soils have an A_1 horizon of dark grey sand, an A_2 horizon of greyish brown sand and a B horizon of pale brown, yellowish brown or yellow

Table 5
Description and Analyses of a Gn Soil
Sample Site: 4 Vegetation: *Eucalyptus obliqua-E. radiata* dry sclerophyll forest

Depth (in.)	Horizon	Description	pH	$CaCO_3$ (%)	P (%)	Gravel (%)
0–3	A_1	Very dark grey organic gravelly sand	5·9	nil	0·018	30
3–6	A_2	Greyish brown gravelly sand	5·8	nil	0·015	30
6–12	B	Yellowish brown gravelly loamy sand	6·1	nil	0·016	40
24–36	B	Dark yellowish brown gravelly sandy loam..	6·0	nil	0·017	63

loamy sand to light sandy clay loam. They are always gravelly throughout the profile. A description and some analyses of a Gn soil are given in Table 5. The content, however, is more than twice that of the Uc2.22 profile, due to the continual profile is acidic throughout, and has a low phosphorus content. The phosphorus content, however, is more than twiec that of the Uc2.22 profile, duc to the continual release of phosphorus by weathering of the granite, whereas in the Uc2.22 profile the phosphorus-rich shell grit has been removed entirely by leaching.

These soils may grade into skeletal soils, or can be up to 6 ft deep. This variation can be related mainly to (a) rates of erosion varying with topography and (b) variable resistance of the granite to weathering—e.g. large granite boulders were found embedded in decomposing granite.

(ii) Dy Soils

A few areas of duplex soils with yellow clay B horizons (Dy soils) were found. In general these soils have an A horizon of dark greyish brown sand to sandy loam 3 to 6 in. thick over a greyish brown to light olive brown sandy clay with red and yellow mottling. This may continue for up to 6 ft, passing gradually into decomposing granite. These soils are also gravelly throughout the profile (see Table 6 for description and analyses). The analyses for the only profile examined show a slightly lower phosphorus content and a more acidic subsoil than the Gn profile analyses.

TABLE 6

Description and Analyses of a Dy Soil

Sample Site: 2 Vegetation: *Eucalyptus baxteri* sclerophyll shrub woodland

Depth (in.)	Horizon	Description	pH	$CaCO_3$ (%)	P (%)	Gravel (%)
0–3	A	Dark greyish brown gravelly loamy sand	6·2	nil	0·015	39
3–6	B	Greyish brown gravelly sandy clay	5·6	nil	0·012	44
6–12	B	Greyish brown gravelly sandy clay	5·7	nil	0·010	67
12–24	B	Light olive brown gravelly sandy clay with red mottling	5·4	nil	0·012	69
24–36	B	Light olive brown gravelly sandy clay with red mottling	5·1	nil	0·012	38

(iii) Uc4.11 Soils

These skeletal soils consist of up to 12 in. of soil over granite bedrock. The profile has an A_1 horizon of greyish brown sand to loamy sand over an A_2 horizon of yellowish brown sand to loamy sand on bedrock. Both horizons are very gravelly. These soils occur near outcropping granite, on granite boulders close to the soil surface, or on steep slopes where weathering and erosion are in equilibrium.

(iv) Gn Soils on Granitic Colluvium

A small area of these was located (see Fig. 5) at the foot of a granite slope. One profile was examined in detail. The description is as follows:

Depth (in.)	
0-10	light yellowish brown gravelly sandy clay loam
10-24	reddish brown gravelly sandy clay
24-62	reddish yellow gravelly sandy clay loam
62-82	mottled reddish yellow, brown, grey gravelly sandy loam
82	gravel

This is a Gn soil, but differs from the other Gn soils on granite in the finer textured surface horizon and in the redder colours.

(c) Peaty Soils

In the most poorly drained portions of the study area, a water table is present at or near the surface for most of the year, providing more or less anaerobic conditions which inhibit the decomposition of organic matter. As a consequence, the soils in these areas are high in organic matter (peaty), varying from peaty sand to amorphous and fibrous peats consisting almost entirely of organic matter.

In classifying these soils, it was impossible to rigidly apply Northcote's (1965) system in the field. Laboratory analysis is necessary to determine whether a soil contains the 20% organic matter necessary for it to be regarded as an organic (O) primary profile form. Therefore, in the field it was necessary to determine subjectively whether any given horizon should be classified as an organic sand, peaty sand, sandy peat, or peat (in increasing order of organic content).

(i) Peaty Sands and Sandy Peats

These soils are made up of the partly decomposed amorphous remains of *Melaleuca ericifolia* and/or *M. squarrosa*, with a clearly visible sand content. A description and some analyses of one such soil is given in Table 7.

Table 7

Description and Analyses of an O Soil

Sample Site: 1 Vegetation: *Melaleuca ericifolia* thicket

Depth (in.)	Horizon	Description	pH	$CaCO_3$ (%)	P (%)
0–3	A	Black amorphous peat with some fine fibrous material	5·5	nil	0·086
3–6	A	Black sandy peat	5·6	nil	0·072
6–12	A	,, ,, ,, ...	5·9	nil	0·053
12–24	A	,, ,, ,, ...	6·1	0·01	0·049
24–36	A–C	Dark grey organic sand with a high shell content in the lower 3 in.	6·9	0·02	0·019

The profile is acidic throughout, but pH increases with depth due to shell-grit from the buried shell bed described earlier. Despite the high figures for % phosphorus, phosphorus usually has a low availability in soils of this type (Hubble 1946).

The soils mapped as peaty sands and sandy peats showed considerable variability of organic content both between and within profiles. Up to 8 ft of sandy peat was recorded, but depths of 5 ft were more usual, diminishing to less than 1 ft of peaty sand in the better drained swamp margins. The water table in all these soils may be more than 1 ft above the soil surface in wet periods, and is close to the surface at other times.

The peaty horizons are underlain by mottled, beach-derived sands which are sometimes cemented into a definite hardpan. A small area of peaty sand was found developed over granite in a poorly drained valley in the granitic hills.

(ii) Amorphous Peats

These soils are similar to the previous group, but are higher in organic matter and have no visible sand content. The peat is again composed principally of the remains of *Melaleuca ericifolia* and *M. squarrosa*, usually with some finely fibrous material present. The profile consists of from 2 ft to 5 ft of amorphous peat over various peat-sand mixtures, which pass into organic sand.

These soils are closely comparable to the Badenoch friable peat described by Stephens (1943).

The amorphous peats occur in the centre of the main swamp area, especially along the banks of Tidal R., presumably in an area of lower relief and poorer drainage than the surrounding sandy peats and peaty sands.

(iii) Fibrous Peats

These soils consist of a coarse fibrous peat, dark brown in colour, and are at least 5 ft in depth. The predominantly coarse fibrous nature of the peat is due to the abundance of sedges growing on them. Sedges are highly resistant to decay compared to *Melaleuca* spp. (Eardley 1943); the important sedges on these soils are *Gymnoschoenus sphaerocephalus, Cladium tetragonum, Lepidosperma forsythii,* and *Gahnia* spp. These soils are similar to the Milstead coarse fibrous peat (Stephens 1943) but are deeper and probably more acidic as they are not influenced by calcareous springs.

It seems probable that these soils occur in even more poorly drained positions than the amorphous peats.

(iv) Soils of the Tidal Flats

These soils occur near the mouth of Tidal R. and are subject to pronounced tidal influence. They are usually organic (O) soils. The profile consists of up to 30 in. of dark brown sandy peat with some fibrous material (probably chiefly remains of the dominent *Juncus maritimus*), becoming less organic with depth and passing into brown organic sand. However, sands with little organic matter accumulation also occur. These soils have been mapped together with peaty sands and sandy peats.

The Plant Associations

In general the vegetation classification of Wood and Williams (1960) is followed. However, following Eardley (1943) and Coaldrake (1961) the term thicket has been adopted for very dense stands of tall shrubs (5 ft to 25 ft high) with a poorly developed understory. Using Wood and Williams's symbols, this structural form has the formula vd S_1G. This creates a structural form intermediate in height between the heath and woodland of Wood and Williams (1960).

The location and extent of the major associations are presented in the vegetation map (Fig. 5).

(a) Plant Associations of the Dunes and Sand Sheets

(i) On Calcareous Sands

The major association on this soil type is the *Leptospermum laevigatum* thicket. This is a characteristic community on stable coastal dunes in many parts of Victoria. It is dominated by *L. laevigatum* (Coastal Tea Tree), which when mature is a shrub up to 24 ft high (Plate 38, fig. 1). *Leucopogon parviflorus* usually occurs in the association either as a tall shrub or as an undershrub. One mature stand examined had a total density of 4,018 shrubs/hectare (2,678 *L. laevigatum*, 1,340 *L. parviflorus*).

The most frequent understory perennials are *Correa alba, Lomandra longifolia, Solanum aviculare, Muehlenbeckia adpressa* var. *hastifolia, Lepidosperma gladi-*

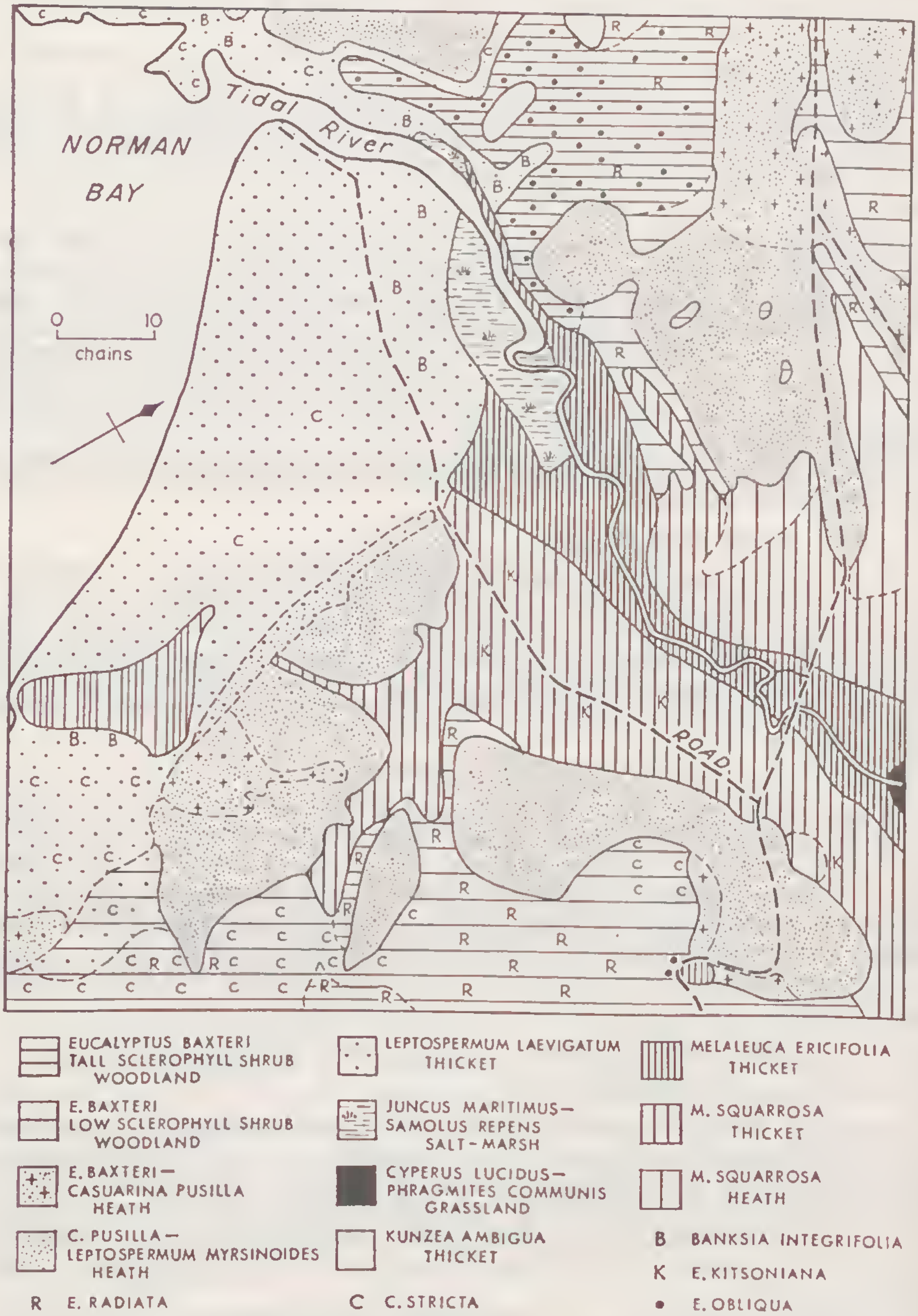

FIG. 5—Vegetation map of the study area.

atum, Senecio glomeratus, Clematis microphylla, Swainsona lessertifolia, Viola hederacea, Geranium potentilloides, Dichondra repens, Acaena sp., and *Poa* sp.

Casuarina stricta trees occur both scattered and in small stands. Less frequently *Banksia integrifolia* (as a tree), *Myoporum insulare,* and *Bursaria spinosa* (both as tall shrubs) occur in the upper stratum.

The *L. laevigatum* thicket occurs principally on the calcareous parallel dunes, and on the lower SE. side of Pillar Point, where calcareous sand has been blown up on to this granitic ridge.

Small areas of *Banksia integrifolia* woodland association also occur on calcareous sands. The dominant *B. integrifolia* is up to 35 ft high. The understory consists of *Pteridium esculentum*, with *Dichondra repens, Scirpus antarcticus,* and other herbaceous species. *B. integrifolia* associations are widespread on calcareous sands elsewhere in Victoria. e.g. at Corner Inlet (Turner, Carr, & Bird 1961).

Poorly drained swales in the calcareous dunes support thickets of *Melaleuca squarrosa* and *M. ericifolia.* These thickets will be fully described later.

(ii) On Siliceous Sands

(1) The *Casuarina pusilla-Leptospermum myrsinoides* heath association:

This is the most widespread association on the siliceous parabolic dunes and deeper sand sheets, dominated by the two sclerophyllous shrubs named above which here are about 2 ft high, having regenerated from the widespread fires of 1951 (Pl. 37, fig. 1). The other most frequent species are *Hypolaena fastigiata, Lepidosperma concavum, Banksia marginata, Isopogon ceratophyllus, Epacris impressa, Leucopogon virgatus, Leucopogon ericoides, Hakea sericea, Xanthorrhoea australis,* and *Lomandra filiforme.*

This association has been referred to as the 'sand heath' by Groves & Specht (1965); it was formerly widespread along the Victorian coast, varying from place to place in species dominance; much of it is now destroyed (see Patton 1933, Gibbons & Downes 1964).

(2) *Eucalyptus baxteri-Casuarina pusilla* heath association:

This differs from the above in that *E. baxteri,* and less frequently, *E. radiata* occur as emergent shrubs at mid-dense to open densities. It occurs on the siliceous sand areas and on the granitic hills. Intermediate structural forms frequently link this heath with sclerophyll shrub woodland.

(3) *Eucalyptus baxteri* low sclerophyll woodland association:

In this association *E. baxteri* occurs as a dense upper stratum (spacing less than twice the diameter of the canopy) with a well developed understory of sclerophyllous shrubs (Pl. 36, fig. 2). For convenience it includes stands where *E. baxteri* occurs either as a tall shrub, or as a low tree. *Eucalyptus radiata* occurs scattered in the upper stratum. *Casuarina stricta* also occurs, especially on shallow soils around granite outcrops.

The most frequently occurring understory species are *Xanthorrhoea australis, Hakea sericea, Haloragis tetragyna, Leptospermum juniperinum, Spyridium parvifolium, Banksia marginata, Banksia spinulosa, Billardiera scandens, Isopogon ceratophyllus, Correa reflexa, Acacia suaveolens, Amperea xiphoclada, Lepidosperma laterale, Hibbertia acicularis, Lomandra filiforme,* and *Casuarina paludosa.*

(4) The *L. laevigatum* thicket association:

The main area where this thicket occurs on siliceous sands is on the siliceous parallel dune. This dune supports both mature thicket with a very sparse understory, and immature thicket with an understory of sclerophyllous shrubs of the *C. pusilla-L. myrsinoides* heath association. This immature thicket can best be regarded as an ecotone between *C. pusilla-L. myrsinoides* heath and *L. laevigatum* thicket rather than as a separate association. Similar immature thickets with sclerophyllous understories occur on some seaward parabolic dunes, and scattered shrubs of *L. laevigatum* occur on the sand sheets, especially in disturbed areas.

(b) Plant Associations of the Granitic Soils

(i) On the Uc4.11 Soils

Areas of these shallow soils are scattered throughout the granitic hills. They carry a number of associations.

(1) The *Kunzea ambigua* association:

This may occur, with various admixtures of *L. laevigatum* and *Hakea sericea*, as a heath 2 ft to 5 ft high, or as a dense thicket 12 ft high with some scattered *L. laevigatum*, *Phyllanthus gunnii*, and *Bedfordia salicina* as tall shrubs, and a sparse understory of *Pteridium esculentum*, *Acaena* sp., *Geranium potentilloides*, and other herbaceous perennials.

(2) *Leptospermum laevigatum* communities:

On these soils *L. laevigatum* occurs mainly on the exposed NW. facing lower slopes of Mt Oberon. The *L. laevigatum* thicket here is lower and more open than on the dunes, *Casuarina stricta* is very prominent, and many species from the *Casuarina pusilla-L. myrsinoides* heath association are present. This community grades into *E. baxteri* low sclerophyll shrub woodland, and one example of the ecotone between these two associations is the unmapped *L. laevigatum-Banksia spinulosa* thicket association, 12 ft to 15 ft high, and consisting of tall shrubs of *L. laevigatum*, *B. spinulosa*, *L. juniperinum*, *Hakea sericea*, *Kunzea ambigua*, *E. baxteri*, and *Casuarina stricta* in order of decreasing frequency. *Spyridium parvifolium*, *Casuarina pusilla*, and some other sclerophyllous species occur in the understory.

(3) The *Casuarina stricta* woodland association:

Small patches of this association occur very frequently throughout the granitic hills on Uc4.11 soils. The tree stratum is usually pure and dense, and there is practically no understory.

(ii) On Gradational (Gn) and Duplex (Dy) Soils

The most common association is the *E. baxteri* low sclerophyll shrub woodland described above. Areas of the *E. baxteri* tall sclerophyll shrub woodland also occur. This association consists of trees of woodland from 30-50 ft high. There is a continuous gradation to low sclerophyll shrub woodland. The tall woodland is a mixture of *E. baxteri*, *E. obliqua*, and *E. radiata*, with *E. baxteri* usually predominating. The area mapped as *E. baxteri* tall sclerophyll shrub woodland on the granitic soils of Pillar Point is probably more accurately described as an *E. obliqua-E. baxteri* association. In places, almost pure stands of *E. obliqua* occur, with a few trees of *E. radiata*. However, on the Mt Oberon slopes, *E. obliqua* was found only in one sheltered swampy gully with an understory of *Melaleuca ericifolia*; the rest of the tall sclerophyll shrub woodland there consists of *E. baxteri* with scattered *E. radiata.*

The most frequent species in the understory are *Pteridium esculentum, Haloragis tetragyna, Banksia spinulosa, Lomandra longifolia, Diplarrhena moraea, Spyridium parvifolium, Lepidosperma laterale, Epacris impressa, Hibbertia aspera, Tetrarrhena juncea,* and *Danthonia* sp.

(c) Plant Associations of the Peaty Soils

(i) On Peaty Sands, Sandy Peats, and Amorphous Peats

(1) The *Juncus maritimus-Samolus repens* association:

Just inland from the mouth of Tidal R. the soils vary from more or less undifferentiated sands to sandy peats grading at 30 in. into sand. They support a salt marsh mostly dominated by *Juncus maritimus* and *Samolus repens,* with *Selliera radicans, Gahnia filum, Salicornia quinqueflora,* and *Stipa teretifolia.* The last two species may become locally dominant.

(2) The *Melaleuca ericifolia* thicket association:

This community is found inland from the salt marsh on soils ranging from peaty sands to amorphous peats. The dominant species can reach 25 ft. The association is difficult to define as the component species change with distance from the sea.

Where the thicket adjoins the salt marsh the following species form a clearly defined ground layer: *Salicornia quinqueflora, Selliera radicans, Samolus repens,* and *Apium australe* (Pl. 37, fig. 2). However, the *M. ericifolia* thicket extends along both banks of Tidal R. for almost its whole distance through the study area. As the distance from the sea increases, the salt-marsh plants drop out of the community, scattered tall shrubs of *Acacia verticillata* occur, and the understory comprises scattered plants of *Gahnia* sp., *Goodenia ovata,* and *Poa* sp.

With increasing distance from Tidal R., *M. squarrosa* replaces *M. ericifolia.* However, these two species occur as co-dominants in a smaller swamp area in a dune hollow surrounded by *L. laevigatum* association near the SE. margin of the parallel dunes. In this *M. ericifolia-M. squarrosa* association, *Acacia verticillata* and *Helichrysum dendroideum* are also prominent, and the understory is dominated by *Gahnia* sp.

A small area of *M. ericifolia* thicket was also found on peaty soils in a wet gully in the granitic Mt Oberon slopes. The stand was 35 ft high with scattered *E. obliqua* trees up to 60 ft high.

(3) The *M. squarrosa* thicket association:

The most widespread of the swamp communities is the *Melaleuca squarrosa* thicket association. This occurs adjacent to the *M. ericifolia* association. The upper stratum is usually about 12 ft high. It includes scattered plants of *Acacia verticillata* and *Helichrysum dendroideum. Gahnia* sp. is the dominant understory species. The other most frequent ones are *Gleichenia microphylla, Phragmites communis, Pultenaea stricta, Leptospermum juniperinum, Haloragis tetragyna, Goodenia ovata, Leucopogon australis, Calorophus lateriflorus, Billardiera scandens, Bauera rubioides,* and *Leptocarpus* sp.

Eucalyptus kitsoniana occurs scattered through the drier areas of the association, and a few specimens of *E. ovata* were also found in this habitat. The underlying soils range from peaty sands to amorphous peats.

(ii) On Fibrous Peats

In places, the *Melaleuca squarrosa* thicket association grades into an association in which the *M. squarrosa* is lower (5 to 6 ft high) and more open (dense to mid-dense). This has been designated the *M. squarrosa* heath association. The *M. squarrosa* is usually slightly emergent above a dense assemblage of smaller swamp plants, of which the following are the most frequent: *Gymnoschoenus sphaerocephalus, Pultenaea stricta, Lepidosperma forsythii, Gleichenia microphylla, Cladium tetragonum, Gahnia* sp., *Restio tetraphyllus, Leptocarpus* sp., *Calorophus lateriflorus, Bauera rubioides, Leptospermum juniperinum, Epacris obtusifolia, Epacris lanuginosa,* and *Sprengelia incarnata* (Pl. 38, fig. 2. This association may deviate from heath form by the scattered occurrence of shrubs of *M. squarrosa, Acacia verticillata, Hakea teretifolia,* and *H. nodosa* up to 12 ft high. The association occasionally occurs over sandy peats with little fibrous material in the profile.

At the inland limit of Tidal R. in the study area, the western edge of a large stand of *Cyperus lucidus-Phragmites communis* grassland occurs. The association consists almost entirely of the two dominants with a few very scattered plants of *Cladium junceum*. The stand is 4 ft to 6 ft high and occurs in a large swamp subject to continual submergence (Pl. 38, fig. 4).

The Relationships between the Plant Associations and Soil Type

The general relationships of the plant associations have been summarized in Table 8.

(a) The *Leptospermum laevigatum* Thicket

This association can occur on calcareous sands, leached siliceous sands and the whole range of granitic soils. It is therefore tolerant of a wide range of nutrient regimes. *L. laevigatum* is absent from poorly drained sites, and its occurrence on freely draining sand soils and on shallow (Uc4.11) soils over granite indicates a tolerance for the driest sites in the study area, along with *C. pusilla-L. myrsinoides* heath on freely draining leached sands, and *Kunzea ambigua* heath on the shallowest of the Uc4.11 soils.

The largest area of *L. laevigatum* thicket is on the calcareous dunes. The leeward edge of these dunes supports scattered trees of *Banksia integrifolia* as an upper stratum over *L. laevigatum*. This suggests that where physiographic protection is adequate, succession to *B. integrifolia* woodland may take place, as proposed by Turner, Carr, & Bird (1961) at Corner Inlet. The presence of charred *B. integrifolia* stumps in some sheltered *L. laevigatum* areas suggests that in some places *L. laevigatum* thicket is being maintained by fire.

The seaward calcareous dunes are exposed to strong winds carrying salt spray. Exclusion of *B. integrifolia* woodland from seaward dunes is probably due to a combination of chloride toxicity caused by salt spray (see Boyce 1954), higher evapotranspiration and possibly mechanical damage due to wind.

The prime importance of shelter from salt spray and wind is demonstrated by Pidgeon's (1942) observation of a *Eucalyptus pilularis-E. botryoides* forest on dunes (presumably siliceous) a few feet from the water's edge in a sheltered inlet on the New South Wales coast. On exposed coastlines in this area, foredunes carry a *L. laevigatum* community as at Tidal R.

Establishment of eucalypts anywhere on the calcareous sand areas is unlikely. Eucalypts are unknown from calcareous beach sands in Victoria and a pot experiment at present in progress shows that *E. baxteri* becomes severely chlorotic

TABLE 8

General Relationships Between Vegetation, Geology, Soils, Topography, and Drainage . .

Association	Geology	Soils	Topography and Drainage
Leptospermum laevigatum thicket	Pleistocene(?) and Recent(?) sands	Uc1.11, Uc2.22	Parallel and seaward parabolic dunes, freely draining.
L. laevigatum heath	Pleistocene(?) sands and Devonian granite	Uc4.11, Uc2.22	Seaward granitic slopes with or without leached sand cover, exposed to onshore winds bearing salt spray. Freely draining.
Casuarina pusilla-L. myrsinoides heath	Pleistocene(?) sands	Uc2.22, Uc2.33	Leeward parabolic dunes and sand sheets. Freely draining (Uc2.22), or on exposed areas of Uc2.33 (internal drainage restricted).
Eucalyptus baxteri-C. pusilla heath	Pleistocene(?) sands and Devonian granite	Uc2.22, Uc2.33, Uc4.11	Leeward parabolic dunes and sand sheets, freely draining (Uc2.22) or internal drainage restricted (Uc2.33). Exposed areas on granitic slopes (Uc4.11).
E. baxteri low sclerophyll shrub woodland	Pleistocene(?) sands and Devonian granite	Uc2.33, various Gn and Dy soils	Lower slopes of parabolic dunes and sand sheets receiving regional drainage. Moderately sheltered granitic hillslopes.
E. baxteri tall sclerophyll shrub woodland	Devonian granite	Various Gn and Dy soils	Sheltered granitic hillslopes and gullies receiving regional drainage.
Kunzea ambigua heath	Devonian granite	Uc4.11	Exposed granitic ridges and hilltops with very shallow soils.
K. ambigua thicket	Devonian granite	Uc4.11	Granitic slopes with very shallow soils.
Casuarina stricta woodland	Devonian granite	Uc4.11	Granitic slopes.
Banksia integrifolia woodland	Recent(?) sands	Uc1.11	Sheltered gullies with a calcareous sand cover.
Juncus maritimus-Samolus repens salt marsh	Recent swamp deposits	Peaty sand, sandy peat	Tidal flats, frequent tidal inundation.
Cyperus lucidus-Phragmites communis	Recent swamp deposits	Sandy peat	Flat, more or less permanently waterlogged.
Melaleuca ericifolia thicket	Recent swamp deposits	Peaty sand, sandy peat, amorphous peat	Flats, dune hollows, gullies subject to tidal or freshwater inundation, water table always high.
M. squarrosa thicket	Recent swamp deposits	Peaty sand, sandy peat, amorphous peat	Flats, dune hollows subject to freshwater inundation, water table always high.
M. squarrosa heath	Recent swamp deposits	Fibrous peat, sandy peat	Depressions, water table always high.

when grown on these soils. It is probable that none of the eucalypts in the study area are adapted to the specialized nutrient conditions of the calcareous sands.

The areas where *L. laevigatum* was recorded from granitic soils are all exposed to strong winds carrying salt spray (as on the seaward Mt Oberon slopes). Field and experimental evidence indicates that *L. laevigatum* is one of the most salt spray tolerant plants in the study area, and that its reduced size in exposed coastal localities is due principally to the toxic effects of salt spray. In the most exposed coastal localities, both in the study area and elsewhere in Victoria (e.g. at Point Lonsdale) the *L. laevigatum* community is reduced in size to a heath by exposure to salt bearing winds.

The absence of *Acacia longifolia* var. *sophorae* from the present foredunes, compared to its prominence elsewhere on the Promontory (e.g. at Darby R.), at Corner Inlet (Turner, Carr, & Bird 1962) and the N.S.W. coast (Pidgeon 1942), is probably due to the removal of the pioneer stages of the dune succession by storm waves. (*Acacia longifolia* var. *sophorae* usually occurs as a pioneer shrub on beach and dunes (Pidgeon 1942).)

(b) The Associations of the Siliceous Sands

The sand heath (*Casuarina pusilla-Leptospermum myrsinoides* association) dominates the driest sites in the leached sand areas, and in particular the freely draining Uc2.22 soils. It also occupies areas of Uc2.33 soils exposed to strong winds, e.g. *C. pusilla-L. myrsinoides* heath is found on the exposed siliceous sand sheet on top of Pillar Point on Uc2.33 soils with a hardpan at 30 in. In areas of greater water availability *Eucalyptus baxteri* and *E. radiata* occur, and *Leptospermum juniperinum* and *Xanthorrhoea australis* become important constituents of the shrub stratum.

The *C. pusilla-L. myrsinoides* association is probably excluded from the calcareous sands by nutritional factors, combined with competition from *L. laevigatum*. There is definite evidence that the occupation of part of the siliceous parallel dune and some areas of the seaward parabolic dunes by *Leptospermum laevigatum* is the result of its invasion of the *C. pusilla-L. myrsinoides* heath, and an examination of the ecotone between *L. laevigatum* thicket and heath suggests that this invasion is still proceeding. The reasons for this are at present being studied by Miss J. P. Burrell, Botany Department, University of Melbourne.

The occurrence of *C. pusilla-L. myrsinoides* heath on deep siliceous sands with unconsolidated B horizons at depths up to 10 ft, indicates a tolerance for the driest and most infertile sites in the siliceous sand areas.

E. baxteri-C. pusilla heath is commonly found in locally wetter areas than the adjacent *C. pusilla-L. myrsinoides* heath, e.g. in hollows between parabolic dunes, and on sand sheet areas where drainage is impeded by the underlying granite.

E. baxteri low sclerophyll shrub woodland occurs in the wettest sites on leached sands. A fringe of low sclerophyll shrub woodland was almost invariably found as a zone between *C. pusilla-L. myrsinoides* heath on freely draining leached sands and *Melaleuca squarrosa* thicket on water-logged peaty soils. Around swamp margins, the following sequence occurs with increasingly poor drainage; *C. pusilla-L. myrsinoides* heath, a narrow zone of heath dominated by *Xanthorrhoea australis,* a zone of *E. baxteri* low sclerophyll shrub woodland about 12 ft high and usually one to two shrubs wide, and finally *M. squarrosa* thicket (Pl. 37, fig. 3).

On leached sands, then, the plant associations may be ranked along a gradient of increasing available water as follows: *C. pusilla-L. myrsinoides* heath, *E. baxteri-C. pusilla* heath, and *E. baxteri* low sclerophyll shrub woodland. The most important single determinant of moisture regime on the leached sands is topographic position. This in turn determines presence of, and depth to a hardpan, as well as degree of exposure to wind and radiation and the amount of regional drainage.

Because of the relationship between topography and hardpan occurrence, it is difficult to establish whether soil fertility is also implicated in the delineation of the plant associations listed above. Decreasing depth to the hardpan not only increases water availability, but also makes the comparatively nutrient-rich hardpan more accessible to plant roots.

(c) The Associations of the Granitic Soils

On granitic areas, the plant associations show a definite sequence with soil properties. The shallowest soils around outcropping granite support a *Kunzea ambigua* heath. Where these soils receive regional drainage, a *K. ambigua* thicket may develop. Slightly deeper soils support *Casuarina stricta* woodland, and this gives way to *E. baxteri* low sclerophyll shrub woodland on soils deeper than about one foot. In gullies and on the sheltered (SE.) side of Pillar Point, an *E. baxteri* tall sclerophyll shrub woodland develops. Granitic soils in the most wind exposed inland positions support an *E. baxteri-Casuarina pusilla* heath, while in coastal positions exposed to wind and salt spray they support stunted *L. laevigatum,* usually with some other sclerophyllous shrubs.

On granitic areas the plant associations can be ranked along a gradient of increasing available water as follows: *Kunzea ambigua* heath, *K. ambigua* thicket, *Casuarina* stricta woodland, *E. baxteri-C. pusilla* heath, *E. baxteri low* sclerophyll shrub woodland, *E. baxteri* tall sclerophyll shrub woodland, and *E. obliqua* tall sclerophyll shrub woodland.

The soils derived from granite are finer in texture than the leached sands and in this rainfall regime, will have a superior moisture status (for the same depth of soil). On the granitic soils, topography is again the most important determinant of moisture regime, especially in determining total soil depth, degree of exposure and amount of regional drainage.

Once again it is difficult to assess the role of soil fertility in these vegetation changes. Total soil depth not only determines moisture regime, but also the total amount of available nutrients.

The occurrence of *E. obliqua-E. muelleriana* dry sclerophyll forest on deep leached beach sands on the Lilly-Pilly Gully track (adjacent to the study area) at the foot of a granite slope suggests that water relations may be more important than nutrients in determining whether heath, woodland or forest can develop in any given site. However, it is possible that these inherently infertile sands may receive an accession of nutrients from decomposing granite further up the slope.

The associations on granitic soils are similar to those on siliceous sands. The higher nutrient status of the granitic soils does not have a marked effect on plant distribution and many species occur on both soil types. However, the *C. pusilla-L. myrsinoides* heath is not present on the granitic soils (although many of the component species are), and some species, e.g. *Casuarina stricta*, are very rare on siliceous sands. As *C. stricta* can grow on very shallow granitic soils, it would appear that it is excluded from the siliceous sands by their low nutrient status rather than by their inferior moisture status for the same depth of soil.

(d) The Associations of the Peaty Soils

The area behind the mouth of Tidal R. supports a *Juncus maritimus-Samolus repens* association. This salt marsh is maintained by frequent tidal inundation combined with adequate physiographic protection from wave erosion. A detailed account of floristically almost identical salt marshes on the Auckland Isthmus, N.Z., is given by Chapman & Ronaldson (1958).

The rest of the area along the banks of Tidal R., inland from the salt marsh, supports a *Melaleuca ericifolia* thicket association. The soils supporting this association range from amorphous peats to peaty sands. These soils are all poorly drained and subject to inundation. This inundation can be caused both by banking up of river water by the incoming tide, and by the incoming tide itself. The strip of *M. ericifolia* thicket along the banks of Tidal R. is subject to varying degrees of tidal influence—during conditions of high spring tides and strong off-shore winds, seawater penetrates all that part of Tidal R. included in the study area.

The ecotone between the *J. maritimus-S. repens* association and the *M. ericifolia* association has been disturbed by recent fires, and it was not possible to establish whether succession to *M. ericifolia* thicket is occurring along the landward margin of the salt-marsh.

Bird (1962) has examined the relationship between similar salt-marshes and *M. ericifolia* thicket in the swamps bordering the Gippsland lakes. He analysed soils for salinity after a dry period when soil salinity was probably near its maximum. Values for salt-marsh soils were consistently higher, and Bird considered that the limit of salinity tolerance of *M. ericifolia* was in the range of 2·5-3·0%. Thus, soil salt concentration may be one factor preventing *M. ericifolia* from invading salt-marsh. However, both in Gippsland and at Tidal R. the salt-marsh occurs at lower levels than the *M. ericifolia* thicket, and decreased soil aeration as a result of increased inundation cannot be discounted as a factor in the delineation of these communities.

It should be noticed that *M. ericifolia* thicket develops both in areas affected by tides and in poorly drained non-tidal ones (see earlier and Hamilton 1919). The factors favouring the development of either *M. ericifolia* or *M. squarrosa* in fresh water swamps are not known. Fresh water swamps in the study area supported either species or both. Stunted *M. ericifolia* has been recorded on shallow soils on granite on Doughboy I., Corner Inlet (Gillham 1961). In the absence of fire, the *M. ericifolia* thicket can develop into a forest 50-60 ft high, as on King I. (Stephens & Hosking 1932).

A number of communities occur in areas further removed from tidal influence. The most widespread of these communities is the *Melaleuca squarrosa* thicket association. This occurs principally in a large swamp adjacent to Tidal R., but further from the river than the *M. ericifolia* thicket. The *M. squarrosa* thicket may be subject to very occasional tidal inundation. The relationship of *M. squarrosa* thicket to communities on the better drained surrounding sands has been discussed earlier. The factors excluding sclerophyll shrub woodland from the badly drained peaty soils suporting *M. squarrosa* are not known. Poor soil aeration is one possibility. Similarly, Costin (1954) has noticed the absence of trees adapted to wet peaty soils in the Monaro region of N.S.W., and he points out that similar soils in Northern Europe are frequently invaded by willow, alder, or birch, which are eventually replaced by climax deciduous forest.

M. squarrosa heath with *Gymnoschoenus sphaerocephalus* occurs chiefly in depressions adjacent to *M. squarrosa* thicket. These depressions seem to be more waterlogged than the thicket areas, the drainage of which is probably assisted by the proximity of Tidal R. Similarly, Eardley (1943) observed stunting of *M. squarrosa* with increased waterlogging, and Davis (1941) observed *Gymnoschoenus* *sphaerocephalus* replacing *M. squarrosa* under conditions of increased waterlogging. In some areas *M. squarrosa* heath may be a stage in succession to *M. squarrosa* thicket after fire. The *Cyperus lucidus-Phragmites communis* grassland appears to occupy the wettest site in the study area—during the period of the field work, this site was continually submerged.

The associations of the freshwater swamp zone may be tentatively ranked in order of increasing tolerance to waterlogging, as follows: *M. squarrosa* thicket, *M. squarrosa* heath, *C. lucidus-P. communis* grassland. Soil aeration is probably one of the critical factors determining this sequence.

Summary

As is to be expected, a considerable number of interacting factors determine the distribution of the plant communities. However, the distribution of a number of communities is determined by clear-cut habitat factors. Examples of these are the *L. laevigatum* communities, which occupy positions exposed to strong winds carrying salt spray, irrespective of soil type; the salt marsh communities, which occupy soils frequently inundated by salt water; and the *Melaleuca* thickets, which occupy soils which are frequently waterlogged. The suite of communities on siliceous sands are more difficult to characterize—they appear to be determined largely by topographic position which determines water supply and presence and accessibility of the nutrient-rich hardpan. The similar suite of communities on granitic soils are again determined by topographic position, which is the principal determinant of soil depth and regional drainage and hence of water and nutrient supply. The most favourable sites on both siliceous sands and granitic areas support a eucalypt dominated sclerophyll shrub woodland, while on calcareous sands they support a *Banksia integrifolia* woodland—this would appear to be related to the intolerance of the eucalypts in the study area for the low heavy metal availabilities of the calcareous sands.

Acknowledgements

It is a pleasure to acknowledge the assistance of Mr G. Hargreaves with much of the field work, of Mr E. Sonenberg in identifying many plant specimens, of Mr J. Howard in the preparation of Fig. 3, of Mr N. D. Hallam with the photography, and of Professor J. S. Turner and Miss M. Todd who provided some of the calcium carbonate analyses. Finally, I wish to thank Dr R. L. Specht, who initiated the project, and gave valuable assistance throughout. The work was supported by a Melbourne University Research Grant.

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Explanation of Plates

PLATE 36

FIG. 1—A general view of the study area from Mt Oberon.
FIG. 2—*Eucalytus baxteri* low sclerophyll shrub woodland with *Kunzea ambigua* and *Banksia spinulosa* conspicuous in the understory on a shallow granitic soil.

PLATE 37

FIG. 1—*Casuarina pusilla-Leptospermum myrsinoides* heath on a Uc2.33 soil, showing the columnar hardpan.
FIG. 2—*Melaleuca ericifolia* thicket.
FIG. 3—Zonation of communities with increasingly poor drainage on a leached sand area. A—*Casuarina pusilla-Leptospermum myrsinoides* heath. B—Narrow fringe of *Xanthorrhoea australis*. C—Fringe of *Eucalyptus baxteri*. D—*Melaleuca squarrosa* thicket.

PLATE 38

FIG. 1—*Leptospermum laevigatum* thicket on calcareous sand.
FIG. 2—*Melaleuca squarrosa* heath. *Gymnoschoenus sphaerocephalus* in the foreground.
FIG. 3—*Juncus maritimus-Samolus repens* salt-marsh.
FIG. 4—*Cyperus lucidus-Phragmites communis* grassland.

Appendix 1

Native Plant Species Occurring in each of the Major Associations

c = very common f = frequent s = scattered

KEY—

1—*Eucalyptus baxteri* tall sclerophyll shrub woodland
2—*E. baxteri* low sclerophyll shrub woodland
3—*Casuarina pusilla-Leptospermum myrsinoides* heath
4—*Leptospermum laevigatum* thicket
5—*Juncus maritimus-Samolus repens* salt-marsh
6—*Melaleuca ericifolia* thicket
7—*M. squarrosa* thicket
8—*M. squarrosa* heath
9—Sheltered slopes of Pillar Point (including calcareous sands and granitic soils)

Species	1	2	3	4	5	6	7	8	9
Schizaeaceae									
Schizaea asperula N. A. Wakefield							s		
Gleicheniaceae									
Gleichenia circinnata Swartz							s	s	
G. microphylla R.Br.							f	c	
Dennstaedtiaceae									
Hypolepis rugosula (Labill.) J.Sm.						s			
Lindsaya linearis Swartz			s						
Pteridium esculentum (Forst. f.) Nakai	c	f	s	s			s	s	s
Adiantaceae									
Adiantum aethiopicum L.	s								
Aspleniaceae									
Asplenium flabellifolium Cav.		s							
Blechnaceae									
Blechnum nudum (Labill.) Mett. ex Luerss.							s		
B. procerum (Forst. f. Swartz)							s		
Selaginellaceae									
Selaginella uliginosa (Labill.) Spring			s						
Juncaginaceae									
Triglochin striata Ruiz & Pav.					s	s			
Gramineae									
Agrostis avenacea J. F. Gmel.					s	s			
A. billardieri R.Br.				s					
Danthonia spp. incl. *D. setacea* R.Br.	f	s	s	s					
Distichlis distichophylla (Labill.) Fassett					s				
Phragmites communis Trin.						s	f		
Poa spp.	s	s		s	s	s			
Stipa spp. incl. *S. semibarbarta* R.Br. and		s	s	s					
S. compacta D. K. Hughes									
S. teretifolia Steud.					f				
Tetrarrhena distichophylla (Labill.) R.Br.		f	f						
T. juncea R.Br.	f								
Cyperaceae									
Cladium acutum (Labill.) Poir.		s							
C. junceum R.Br.					c	f			
C. tetragonum (Labill.) J. M. Black							f	f	
Cyperus lucidus R.Br.	see text								
Gahnia spp.						s	c	c	
G. filum (Labill.) F. Muell.					c				

	1	2	3	4	5	6	7	8	9
G. trifida Labill.					f	f			
Gymnoschoenus sphaerocephalus (R.Br.) Hook. f.								c	
Lepidosperma canescens Boeck.			s						
L. concavum R.Br.		f	c						
L. elatius Labill.	s								
L. filiforme Labill.			s	s					
L. forsythii A. A. Hamilton							s	c	
L. gladiatum Labill.				f					
L. laterale R.Br.	f	f							
L. semiteres F. Muell. ex Boeck.								s	
Schoenus apogon Roem. & Schult.			s	s					
S. breviculmis Benth.			s						
S. maschalinus Roem. & Schult.							s		
S. tenuissimus Benth.			s						
Scirpus antarcticus L.									s
S. cernuus Vahl					s				
S. fluitans L.									s
S. inundatus (R.Br.) Poir.									s
S. nodosus Rottb.				s	s	s			
Tetraria capillaris (F. Muell.) J. M. Black			s						
RESTIONACEAE									
Calorophus lateriflorus (R.Br.) F. Muell.							f	c	
Hypolaena fastigiata R.Br.			c						
Leptocarpus spp. incl. *L. tenax* (Labill.) R.Br. and *L. brownii* Hook. f.			s		s	s	f	f	
Restio tetraphyllus Labill.							s	c	
CENTROLEPIDACEAE									
Centrolepis fascicularis Labill.			s	s			s		s
XYRIDACEAE									
Xyris operculata Labill.								f	
JUNCACEAE									
Luzula campestris (L.) DC.				f					
Juncus maritimus Lam.					c				
J. pallidus R.Br.						s			
J. pauciflorus R.Br.						s			
J. revolutus R.Br.					f				
LILIACEAE									
Burchardia umbellata R.Br.	s	s	s	s					
Chamaescilla corymbosa (R.Br.) F. Muell. ex Benth.			s						
Dianella revoluta R.Br.	f	f	s	s					
Laxmannia sessiliflora Decaisne			s	s					
Lomandra filiformis (Thunb.) Britten	c	c	c						
L. longifolia Labill.	f	f		s					
Thysanotus patersonii R.Br.			s						
T. tuberosus R.Br.			s						
Xanthorrhoea australis R.Br.		c	f						
IRIDACEAE									
Diplarrhena moraea Labill.	f	f							
Patersonia fragilis (Labill.) Druce		s	s						
P. glabrata R.Br.		s							
ORCHIDACEAE									
Acianthus reniformis (R.Br.) Schlechter			s	s					
Caladenia caerulea R.Br.			s						
C. carnea R.Br.			s						

	1	2	3	4	5	6	7	8	9
C. clovigera A. Cunn. ex Lindl.			s						
C. deformis R.Br.			s						
C. latifolia R.Br.				s					
Corybas diemenicus (Lindl.) H.M.R. Rupp			s						
Diuris longifolia R.Br.			s						
Glossodia major R.Br.			s						
Lyperanthus nigricans R.Br.			s						
Prasophyllum elatum R.Br.			s						
Pterostylis vittata Lindl.			s						
Thelymitra antennifera (Gunn ex Lind.) Hook. f.			s						
CASUARINACEAE									
Casuarina paludosa Sieber ex Spreng.		f							
C. pusilla Macklin		f	c						
C. stricta Dryand.		f		s					
PROTEACEAE									
Banksia integrifolia L.f.				s					s
B. marginata Cav.	s	c	c						
B. serrata L.f.			s						
B. spinulosa Sm.		c	s						
Hakea nodosa R.Br.								s	
H. sericea Schrad. & J. Wendl.	f	c	s						
H. teretifolia (Salisb.) J. Britt.								s	
H. ulicina R.Br.		s	s						
Isopogon ceratophyllus R.Br.		c	c						
Persoonia juniperina Labill.		s	s						
SANTALACEAE									
Exocarpos cupressiformis Labill.			s						
POLYGONACEAE									
Muehlenbeckia adpressa (Labill.) Meissn.				f					
Polygonum strigosum R.Br.						s			
CHENOPODIACEAE									
Chenopodium gloucum L.						s			
Hemichroa pentandra R.Br.					s				
Rhagodia baccata (Labill.) Moq.				s					
Salicornia quinqueflora Bunge ex Ung. Sternb.					c				
Suaeda austrolis (R.Br.) Moq.				s	s				
AIZOACEAE									
Disphyma austrole (Soland.) J. M. Black				s					
Tetragonia implexicoma (Miq.) Hook. f.				f					
CARYOPHYLLACEAE									
Colobanthus opetalus (Labill.) Druce				s					
Sagina apetala L.				s					
Spergularia media (L.) C. Presl.					s				
Stellaria pungens Brongn.		s							
RANUNCULACEAE									
Clematis aristata R.Br. ex DC.						s			s
C. microphylla DC.				f					
MONIMIACEAE									
Hedycarya angustifolia A. Cunn.									s
LAURACEAE									
Cassytha glabella R.Br.	s	f	f						
C. pubescens R.Br.	s	f	s			s	f	f	

	1	2	3	4	5	6	7	8	9
CRUCIFERAE									
Cakile edentula (Bigel.) Hook. subsp. *californica* (Heller) Hult.				s	s				
Hymenolobus procumbens (L.) Nutt. ex J. M. Black				s					
DROSERACEAE									
Drosera auriculata Backh. ex Planch.		s							
D. planchonii Hook. f.		s	f						
D. pygmaea DC.		s							
CUNONIACEAE									
Bauera rubioides Andr.							f	f	
PITTOSPORACEAE									
Billardiera scandens Sm.		c	s				f		
Bursaria spinosa Cav.				s					s
Marianthus procumbens (Hook.) Benth.		s	s						
ROSACEAE									
Acaena sp.				f		s	s		f
Rubus triphyllus Thunb.				s					
MIMOSACEAE									
Acacia myrtifolia (Sm.) Willd.		s	s						
A. retinodes Schlechtendal var. *oraria* J. M. Black				s		s	s		
A. stricta (Andr.) Willd.				s					
A. suaveolens (Sm.) Willd.		c	s				s	s	
A. verticillata (L'Her.) Willd.	s	s	s			f	f	s	
PAPILIONACEAE									
Aotus ericoides (Vent.) G. Don		f	f					s	
Bossiaea cinerea R.Br.			s						
B. prostrata R.Br.		s	s						
Daviesia ulicifolia Andr.		s	s						
Dillwynnia sericea A. Cunn.			s						
D. glaberrima Sm.		f	c						
Glycine clandestina J. Wendl.						s			
Gompholobium huegelii Benth.			s						
G. minus Sm.		s	s						
Kennedia prostrata R.Br.		s	s	s					
Platylobium obtusangulum Hook.		s	s						
Pultenaea daphnoides J. Wendl.	f	f	s						
P. scabra R.Br.		s	s						
P. stricta Sims							f	c	
Swainsona lessertiifolia DC.				f		s			
Viminaria juncea (Schrad. & J. Wendl.) Hoffmannsegg							s	s	
OXALIDACEAE									
Oxalis corniculata L.	s	s	s	s		s	s		s
GERANIACEAE									
Geranium potentilloides L'Herit. ex Ait.	s			f					s
Pelargonium australe Willd.									s
RUTACEAE									
Correa alba Andr.				f					
C. reflexa (Labill.) Vent.	f	c	f						
TREMANDRACEAE									
Tetratheca ciliata Lindl.	f	f							
T. pilosa Labill.		f	f						

	1	2	3	4	5	6	7	8	9
POLYGALACEAE									
Comesperma calymega Labill.			s						
C. volubile Labill.	s	s	s	s					
EUPHORBIACEAE									
Amperea xiphoclada (Sieber ex Spreng.) Druce		c	c						
Phyllanthus gunnii Hook. f.		s							
Poranthera microphylla Brongn.				s					s
STACKHOUSIACEAE									
Stackhousia monogyna Labill.			s						
RHAMNACEAE									
Pomaderris aspera Sieber ex DC.						s			s
P. oraria F. Muell. ex Reiss.				s					f
Spyridium parvifolium (Hook.) F. Muell.	f	c	s						
STERCULIACEAE									
Thomasia petalocalyx F. Muell.				s					
DILLENIACEAE									
Hibbertia acicularis (Labill.) F. Muell.	f	c	f						
H. aspera DC.	f	f							
H. fasciculata R.Br. ex DC.		s	c						
H. procumbens (Labill.) DC.			s						
H. sericea (R.Br. ex DC.) Benth.	f	f	f						
H. virgata R.Br. ex DC.			s						
VIOLACEAE									
Viola hederacea Labill.	s	s	s	f		s	s		f
V. sieberiana Spreng.									s
THYMELAEACEAE									
Pimelea spp. incl. *P. humilis* R.Br.		s	c						
MYRTACEAE									
Baeckea ramosissima A. Cunn.		s	c						
Calytrix tetragona Labill.		s	f						
Eucalyptus baxteri (Benth.) Maiden et Blakely	c	c	f						
E. kitsoniana Maiden							s		
E. obliqua L'Hér.	f								
E. ovata Labill.							s		
E. radiata Sieber ex DC.	f	f	s						
Kunzea ambigua (Sm.) Druce	f	f	f						
Leptospermum juniperinum Sm.	s	c	s			s	f	c	s
L. laevigatum (Gaertn.) F. Muell.			f	c					c
L. lanigerum (Ait.) Sm.						s	s	s	
L. myrsinoides Schlecht.		f	c						
Melaleuca ericifolia Sm.						c	f		
M. squarrosa Labill.						f	c	c	s
HALORAGACEAE									
Haloragis tetragyna (Labill.) Hook. f.	c	c	f				f	f	
Myriophyllum amphibium Labill.						s			s
UMBELLIFERAE									
Apium prostratum Labill.				s	f	s			
Hydrocotyle callicarpa Bunge				s			s		
Lilaeopsis australica (F. Muell.) A. W. Hill					s				
Platysace heterophylla (Benth.) Norman		s	f						
Xanthosia dissecta Hook. f.			s						

	1	2	3	4	5	6	7	8	9
X. pusilla Bunge			s						
X. tridentata DC.		s	s						
EPACRIDACEAE									
Acrotriche serrulata (Labill.) R.Br.	f	f	s						
Astroloma humifusum (Cav.) R.Br.		s	s	s					
Epacris impressa Labill.	c	c	c						
E. lanuginosa Labill.								c	
E. obtusifolia Sm.								c	
Leucopogon australis R.Br.	s						f	f	s
L. ericoides (Sm.) R.Br.		s	c						
L. parviflorus (Andr.) Lindl.				c					
L. virgatus (Labill.) R.Br.		s	c						
Monotoca elliptica (Sm.) R.Br.		s							
M. scoparia (Sm.) R.Br.			s						
Sprengelia incarnata Sm.								c	
PRIMULACEAE									
Samolus repens (Forst. et Forst. f.) Pers.					c	f			
GENTIANACEAE									
Centaurium spp.			s	f					
APOCYNACEAE									
Alyxia buxifolia R.Br.				s					
CONVOLVULACEAE									
Dichondra repens Forst. et Forst. f.				c		s	s		c
BORAGINACEAE									
Cynoglossum australe R.Br.				s					
SOLANACEAE									
Solanum aviculare Forst. f.				f					
S. vescum F. Muell.				s					
SCROPHULARIACEAE									
Mazus pumilio R.Br.							s		
Veronica calycina R.Br.				s					
V. derwentia Andr.									s
BIGNONIACEAE									
Pandorea pandorana (Andr.) Steenis									s
LENTIBULARIACEAE									
Utricularia dichotoma Labill.							s		
U. lateriflora R.Br.							s		
MYOPORACEAE									
Myoporum insulare R.Br.				s		s			s
PLANTAGINACEAE									
Plantago debilis R.Br.									s
RUBIACEAE									
Coprosma quadrifida (Labill.) Robinson							s		
Galium australe DC.				s					s
G. gaudichaudii DC.				s					s
Opercularia ovata Hook. f.			s						
O. varia Hook. f.		s	f						

	1	2	3	4	5	6	7	8	9
CAPRIFOLIACEAE									
Sambucus gaudichaudiana DC.				s					s
CAMPANULACEAE									
Lobelia alata Labill.					f				
L. gibbosa Labill.				s					
Wahlenbergia spp.				s					
GOODENIACEAE									
Goodenia ovata Sm.						s	f		
Scaevola pallida R.Br.				s					s
Selliera radicans Cav.					c	s			
STYLIDIACEAE									
Stylidium graminifolium Swartz.	f	f	s						
COMPOSITAE									
Bedfordia salicina (Labill.) DC.		s							
Brachycome diversifolia (R. Graham ex Hook.) Fisch. & C. Mey.									s
B. graminea (Labill.) F. Muell.					s				
Cassinia spectabilis (Labill.) R.Br.				s					
Cotula coronopifolia L.					f	s			
C. reptans (Benth.) Benth. var *major* Benth.					f				
C. vulgaris Levyns var. *australasica* J. H. Willis				s					
Gnaphalium candidissimum Lam.									s
G. japonicum Thunb.						s			
G. luteo-album L.						s			
Helichrysum apiculatum (Labill.) DC.									s
H. baxteri A. Cunn. ex DC.			s						
H. dendroideum N. A. Wakefield						f	f		f
H. gunnii (Hook. f.) Benth.				s					
H. obtusifolium F. Muell. et Sond. ex Sond.			s	s					
H. scorpioides Labill.	f	f	f						
Lagenophora stipitata (Labill.) Druce			s	s			s		
Olearia argophylla (Labill.) Benth.									s
O. axillaris (DC.) Benth.				s					
O. ciliata (Benth.) Benth.		f	f						
O. glutinosa (Lindl.) Benth.				s					
O. phlogopappa (Labill.) DC.							s		s
O. lirata (Sims) Hutch.							s		
O. ramulosa (Labill.) Benth.									s
O. rugosa (F. Muell. ex Archer) Hutch.	c	f					s		
Senecio glomeratus Desf. ex Poir.				c					c
S. hispidulus A. Rich.				s	s	s			
S. lautus Forst. f. ex Willd.			s	f					
S. minimus Poir.				s					s
Sigesbeckia orientalis L.				s					

Appendix 2

A Preliminary List of the Naturalized Alien Species Occurring in Each of the Major Associations

(Many of these species occur in disturbed areas within the plant associations indicated)

1—*Eucalyptus baxteri* tall sclerophyll shrub woodland
2—*E. baxteri* low sclerophyll shrub woodland
3—*Casuarina pusilla-Leptospermum myrsinoides* heath
4—*Leptospermum laevigatum* thicket
5—*Juncus maritimus-Samolus repens* salt-marsh
6—*Melaleuca ericifolia* thicket
7—*M. squarrosa* thicket
8—*M. squarrosa* heath
9—Sheltered slopes of Pillar Point

Species	1	2	3	4	5	6	7	8	9
Gramineae									
Agropyron junceum (L.) Pal. Beauv.				s					
Ammophila arenaria (L.) Link.				s					
Briza maxima L.				s					
Bromus diandrus Roth.				s					
Cynodon dactylon (L.) Pers.				s					
Dactylis glomerata L.				s					
Ehrharta erecta Lam.				s					
E. longiflora Sm.				s					
Holcus lanatus L.				s					
Hordeum leporinum Link.				s					
Lagurus ovatus L.				f					
Lolium perenne L.				s					
Parapholis strigosa (Dumort.) C. E. Hubbard					s				
Pennisetum clandestinum Hochst. ex Chiov.				s					
Sporobolus capensis Kunth.				s					
Caryophyllaceae									
Cerastium glomeratum Thuill.				s					
Papilionaceae									
Medicago lupulina L.				s					
M. minima (L.) L.				s					
Melilotus indica (L.) All.				s					
Trifolium campestre Schreb.				s					
T. repens L.				s					
Euphorbiaceae									
Euphorbia peplus L.				s					
Primulaceae									
Anagallis arvensis L.				s					
Plantaginaceae									
Plantago coronopus L.					s				
Compositae									
Arctotheca calendula (L.) Levyns				f					
Cirsium vulgare (Savi) Ten.				f					f
Conyza bonariensis (L.) Cronquist				s					
Hypochoeris spp.				s		s	s		s
Sonchus spp.				s					s

Appendix 3

Notes on the Distribution of the Tree Species

Eucalytus kitsoniana. In the study area this eucalypt occurs scattered in poorly drained areas with *Melaleuca squarrosa*. It occurs frequently in similar situations elsewhere on the Promontory (e.g. along the Vereker track) as well as at the summit of Mt Oberon in a very exposed position on shallow soils between granite boulders. Other recorded occurrences are in South Gippsland (e.g. around Meeniyan and Stony Ck, Hooke (1959), a few miles E. of Cape Otway (Hooke 1959) and on poorly drained sites in SW. Victoria (Gibbons & Downes 1964)).

E. ovata. Occurs scattered in *Melaleuca squarrosa* swamp.

E. obliqua. Occurs only in sheltered, well-watered sites, and in the study area only on granitic soils. However, on the Lilly-Pilly Gully track, adjacent to the study area, it is found on leached beach sands at the foot of a granitic slope, as a constituent of dry sclerophyll forest, in mixture with *E. muelleriana* and *E. globulus*.

E. baxteri and *E. radiata*. Both species are found on leached beach sands and granitic soils. This occurrence of *E. baxteri* falls within the climatic tolerance range of *E. baxteri* observed by Pidgeon (1941) on infertile soils of the central coast of N.S.W. (described as *E. capitellata* in Pidgeon's figure). However, Pidgeon does not record *E. radiata* at altitudes lower than about 1,800 ft, which indicates a markedly different distribution pattern for this species in central coastal N.S.W. than that at Tidal R.

Banksia integrifolia. This tree is found chiefly on calcareous sands, but occurs occasionally on various granitic soils.

B. serrata. Only two young specimens of this tree were found. They occurred on the sand sheet NE. of Pillar Point, with *C. pusilla-L. myrsinoides* heath. This contrasts with the development of *B. serrata* sclerophyll shrub woodland on leached sands elsewhere on the Promontory (e.g. along the Vereker track).

Casuarina stricta. This tree occurs commonly on calcareous sands and shallow granitic soils, but only very occasionally on leached sands. It can occupy sites of lower moisture status than any other tree in the study area.